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Benzene Emissions from Ethylbenzene/Styrene Plants - Background Information for Proposal to Withdraw Proposed Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

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Office of Air Quality
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Research Triangle Park NC 27711

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16. ABSTRACT

This document contains information that formed the basis for the decision to withdraw standards for the ethylbenzene/styrene industry proposed December 18, 1980 (45 FR 83448). The report includes a summary of industry changes since proposal, a summary of public comments relevant to the withdrawal decision, and the rationale for the decision to withdraw proposed standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Benzene Emissions from Ethylbenzene/Styrene Plants — Background Information for Proposal to Withdraw Proposed Standards

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning Standards
Research Triangle Park, North Carolina 27711

March 1984

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
for Ethylbenzene/Styrene Plants

Prepared by:

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(Date)

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1. The Federal Register notice proposes withdrawal of proposed national emission standards (45 FR 83448; December 18, 1980) for benzene emissions from existing and new ethylbenzene/styrene plants.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; State and Territorial Air Pollution Program Administrators; EPA Regional Administrators; Local Air Pollution Control Officials; Office of Management and Budget; and other interested parties.

3. The comment period for review of this document is 30 days from date of proposal in the Federal Register. Mr. Gilbert H. Wood may be contacted at (919) 541-5578 regarding the date of the comment period.

4. For additional information contact:

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1. SUMMARY

The U.S. Environmental Protection Agency (EPA), on December 18, 1980, proposed a national emission standard for hazardous air pollutants (NESHAP) (45 FR 83448) that would regulate benzene emissions from ethylbenzene/styrene (EB/S) plants under the authority of Section 112 of the Clean Air Act as amended. Public comments were requested on the proposal in the Federal Register publication. Twelve comment letters were received, and six interested parties testified at the public hearing. These comments were made by EB/S manufacturers, the Chemical Manufacturers Association (CMA), and State and Federal Government offices. Comments submitted relevant to the withdrawal decision, along with the responses to these comments, are summarized in this document. The summary of comments and responses serves as the basis for the proposal to withdraw the proposed standards.

1.1 SUMMARY OF INDUSTRY CHANGES SINCE PROPOSAL

Since the standards for benzene emissions from EB/S plants were proposed (December 18, 1980; 45 FR 83448), benzene emissions from this source category have declined considerably. This reduction is due to revised emission estimates, a revised estimate of flare efficiency (from 60 to 98 percent), installation of controls, industry capacity reductions, and better maintenance of existing product recovery units. These changes are described in more detail in Section 2.2.1 of this document. Table 1-1 compares the nationwide baseline benzene emission and health impacts due to EB/S process vents at proposal with current estimated impacts.

TABLE 1-1. CHANGES IN INDUSTRY IMPACTS

Impact	At proposal	Current
Benzene emissions (Mg/yr)	2,400	210
Leukemia incidence (cases/yr)	0.027 to 0.20	0.0057
Maximum lifetime risk	6.2×10^{-4} to 4.4×10^{-3}	1.4×10^{-4}

1.2 SUMMARY OF PROPOSAL TO WITHDRAW THE PROPOSED STANDARDS

The Administrator is proposing to withdraw proposal of the benzene standards for EB/S plants. This decision is based on several factors, including the broad amount of control currently within the source category, the relatively small amount of emissions, the small estimated leukemia incidence and maximum lifetime risk at current control levels, and the small reduction in these health risks achievable with add-on controls. This decision is discussed in greater detail in Section 2.1.1.

2. SUMMARY OF PUBLIC COMMENTS

The commenters and docket numbers are listed in Table 2-1. Twelve letters contained comments and six people testified at the public hearing on the proposed standard and its background information document (BID). Because the proposed standards are being proposed for withdrawal, only comments relevant to that decision are addressed in this document. These comments have been combined into the following two categories:

1. Selection of Ethylbenzene/Styrene (EB/S) Plants for Regulation
2. Health and Environmental Impacts

2.1 SELECTION OF ETHYLBENZENE/STYRENE PLANTS FOR REGULATION

2.1.1 Appropriateness of Regulating EB/S Plants Under Section 112

Comment: Several commenters stated that EB/S plants do not present the magnitude of risk to health for which a national emission standard for hazardous air pollutants (NESHAP) is appropriate. They felt that the risk from benzene emissions from EB/S plants is far below the threshold level for induction of benzene-related leukemia, and therefore, emissions from EB/S plants do not present the kind of health risk that Congress foresaw when it enacted Section 112 to deal with the limited number of very hazardous pollutants (IV-F-1; IV-F-2; IV-F-5; IV-D-10).

Response: At the time the standard was proposed, total EB/S industry-wide process benzene emissions were estimated to be 2,100 Mg/yr based on 100 percent production capacity and actual plant-by-plant control levels. (After publication of the proposal preamble (45 FR 83448), this number was revised to 2,400 Mg/yr because of miscalculations in the industry-wide total.) It was estimated that 2.5 million people live within 20 kilometers of EB/S plants. As a result of exposure to

TABLE 2-1. LIST OF COMMENTERS ON THE PROPOSED NATIONAL EMISSION STANDARD FOR BENZENE EMISSIONS FROM EB/S PLANTS

Commenter[a]	Affiliation
IV-F-1	Public Hearing Transcript
IV-F-2[b]	Chemical Manufacturers Association (CMA)
IV-F-3[b]	Oxirane Chemical/ARCO Chemical
IV-F-4[b]	Dow Chemical
IV-F-5[b]	Applied Meteorology, Inc.
IV-F-6[b]	Cos-Mar
IV-D-1	Wilmer, Cutler, and Pickering (CMA)
IV-D-2	Dow Chemical, U.S.A.
IV-D-3	Federal Energy Regulatory Commission (FERC)
IV-D-4	Department of Environmental Regulation, State of Florida
IV-D-5	Public Health Service, Department of Health and Human Services
IV-D-6	Wilmer, Cutler, and Pickering (CMA)
IV-D-7	Air Products and Chemicals, Inc.
IV-D-8	Wilmer, Cutler, and Pickering (CMA)
IV-D-9	American Petroleum Institute
IV-D-10	Wilmer, Cutler, and Pickering (CMA)
IV-D-11	Dow Chemical, U.S.A.
IV-D-12	Gulf Oil Chemicals

[a]These designaters represent docket entry numbers for Docket Number A-79-49. These docket entries are available for public inspection at:

Central Docket Section
West Tower Lobby, Gallery 1
Waterside Mall
401 M Street, S.W.
Washington, DC 20460

[b]These references are transcripts submitted by commenters at the public hearing and are essentially identical to their oral testimony.

these benzene concentrations, maximum lifetime risk was estimated to be within a range of 6.2×10^{-4} to 4.4×10^{-3}. In addition, a range of leukemia incidence of 0.027 to 0.20 cases per year within this population due to benzene exposure from EB/S plants was estimated. Maximum lifetime risk is the probability of someone within the assumed exposed population contracting leukemia if he or she were exposed to the highest maximum annual average benzene concentration predicted from dispersion modeling during an entire lifetime (70 years).

These ranges represent 95 percent confidence limits on two sources of uncertainty in the benzene risk estimates (II-A-8). One source derives from the variations in dose/response among the three occupational studies upon which the benzene unit risk factor is based. A second source involves the uncertainties in the estimates of ambient exposure. In the former case, the confidence limits are based on the assumption that the slopes of the dose/response relationships are unbiased estimates of the true slope and that the estimates are log normally distributed. In the latter case, the limits are based on the assumption that actual exposure levels may vary by a factor of two from the estimates obtained by dispersion modeling (assuming that source-specific input data are accurate).

Several other uncertainties are associated with the estimated health numbers not quantified in the proposal ranges. EPA has extrapolated the leukemia risks identified for occupationally exposed populations (generally healthy, white males) to the general population for whom susceptibility to a carcinogenic insult could differ. The presence of more or less susceptible subgroups within the general population would result in an occupationally-derived risk factor that may underestimate or overestimate actual risks. To the extent that there are more susceptible subgroups within the general population, the maximum individual lifetime risks may be underestimated.

On the other hand, general population exposures to benzene are much lower than those experienced by the exposed workers in the occupational studies, often by several orders of magnitude. In relating the occupational experience to the general population, EPA has applied a linear, nonthreshold model that assumes that the leukemia response is

linearly related to benzene dose, even at very low levels of exposure. There are biological data supporting this approach, particularly for carcinogens. However, there are also data which suggest that, for some toxic chemicals, dose/response curves are not linear, with response decreasing faster than dose at low levels of exposure. At such levels, the nonlinear models tend to produce smaller risk factors than the linear model. The data for benzene do not conclusively support either hypothesis. EPA has elected to use the linear model for benzene because this model is generally considered to be conservative compared to the nonlinear alternatives. This choice may result in an overestimate of the actual leukemia risks.

EPA estimates ambient benzene concentrations in the vicinity of emitting sources through the use of atmospheric dispersion models. EPA believes that its ambient dispersion modeling provides a reasonable estimate of the maximum ambient levels of benzene to which the public could be exposed. The models accept emissions estimates, plant parameters, and meteorology as inputs and predict ambient concentrations at specified locations, conditional upon certain assumptions. For example, emissions and plant parameters often must be estimated rather than measured, particularly in determining the magnitude of fugitive emissions and where there are large numbers of sources. This can lead to overestimates or underestimates of exposure. Similarly, meteorological data often are not available at the plant site but only from distant weather stations that may not be representative of the meteorology of the plant vicinity.

EPA's dispersion models normally assume that the terrain in the vicinity of the sources is flat. For sources located in complex terrain, this assumption would tend to underestimate the maximum annual concentration although estimates of aggregate population exposure would be less affected. On the other hand, EPA's benzene exposure models assume that the exposed population is immobile and outdoors at their residence, continuously exposed for a lifetime to the predicted concentrations. To the extent that benzene levels indoors are lower and that people do not reside in the same area for a lifetime, these assumptions will tend to overpredict exposure.

Upon reconsideration, EPA has concluded that the presentation of the risk estimates as ranges does not offer significant advantages over the presentation as the associated point estimates of the risk. Further, the proposal ranges for benzene make risk comparisons among source categories more difficult and tend to create a false impression that the bounds of the risks are known with certainty. For these reasons, the benzene risks in this rulemaking are presented as point estimates of the leukemia risk. EPA believes that these risk numbers represent plausible, if conservative, estimates of the magnitude of the actual cancer risk posed by benzene emitted from the source categories evaluated. For comparison, the proposal ranges may be converted into rough point estimates by multiplying the lower end of the range by a factor of 2.6.

When possible, given sufficient health data and appropriate assumptions regarding hazardous air pollutants, estimates are made of cancer incidence and risk in the general population due to ambient exposure around the sources of emissions. Quantitative risk estimates at ambient concentrations involve an analysis of the effects of the substance in high-dose epidemiological or animal studies and extrapolation of these high-dose results to relevant human exposure routes at low doses. The mathematical models used for such extrapolations are based on observed dose-response relationships for carcinogens and assumptions about such relationships as the dose approaches very low levels or zero.

The risks to public health from a carcinogen's emissions may be estimated when the dose-response relationship obtained from this carcinogenicity strength calculation is combined with an analysis of the extent of population exposure to the substance through the ambient air. Exposure in this context is a function of both a substance's concentration and the length of time the concentration is encountered. Exposure analyses are based on air quality models, available estimates of emissions from EB/S plants, and approximations of population distributions near their sources.

The air quality models used estimated exposures of up to 20 kilometers, and population and growth statistics were examined. Along

with the existing carcinogenic strength determinations, the information collected was used to estimate the degree of risk to individuals and the range of increased cancer incidence expected from ambient air exposures associated with EB/S plants at various possible emission levels.

The assumptions necessary to estimate benzene health risks and the underlying uncertainties have led some commenters on EPA's proposed rules to suggest that the risk estimates are inappropriate for use in regulatory decisionmaking. Although EPA acknowledges the potential for error in such estimates, the Agency has concluded that both the unit risk factor for benzene and the evaluation of public exposure represent plausible, if conservative, estimates of actual conditions. Combining these quantities to produce estimates of the leukemia risks to exposed populations implies that the risk estimates obtained are also conservative in nature; that is, the actual leukemia risks from benzene exposure are not likely to be higher than those estimated. In this context, EPA believes that such estimates of the health hazard can and should play an important role in the regulation of hazardous pollutants.

Based on the magnitude of benzene exposures from this source category, the resulting estimated maximum individual risks and leukemia incidence in the exposed population, and consideration of the uncertainties of quantitative risk assessment, the Administrator determined at proposal that benzene emissions from EB/S plants pose a significant cancer risk.

After noting the control status of changes in the EB/S industry since proposal (see Response 2.2.1 of this document), EPA reassessed whether EB/S process vents continue to pose a significant risk of leukemia and whether a benzene standard is warranted under Section 112. EB/S process vents are currently estimated to emit about 210 megagrams of benzene annually from 13 plants. This amount is less than 0.4 percent of total benzene emissions from stationary sources. Estimated lifetime risk due to these emissions is about 1.4×10^{-4} for the most exposed individuals, and over the total exposed population (within

20 km of each plant) about 0.0057 leukemia cases per year is estimated to occur. The current (or baseline) impacts are presented in Table 2-2.

For comparison, at proposal the industry was estimated to emit 2,400 Mg/yr, resulting in a range of leukemia cases per year of about 0.027 to 0.20 and a range of maximum lifetime risk of 6.2×10^{-4} to 4.4×10^{-3}. Thus, since proposal, estimated benzene emissions, estimated annual leukemia incidence, and the estimated maximum lifetime risk have all declined by over 90 percent.

- Combustion control techniques applicable to EB/S process vents were described at proposal and include boilers, incinerators, and flares which can reduce emissions by at least 98 percent. Although at proposal flares were assumed to achieve only 60 percent reduction, this estimate has been revised upward to 98 percent due to the results from recent flare studies (see Section 2.2.2) (IV-A-4; IV-A-5; IV-D-17; IV-J-2; IV-J-3; IV-J-7). These studies indicate that a flare meeting certain operating conditions can achieve emission reductions in this range. Applying these combustion control techniques could reduce nationwide benzene emission from these sources over baseline by about 70 percent.

The current estimated leukemia incidence and maximum lifetime risk represent small risks to public health. By both expressions of health risk, the extent of the hazard posed by this source category is more than an order of magnitude smaller than for benzene source categories for which standards are being developed. Using combustion control techniques, leukemia incidence could be reduced to roughly 0.001 cases per year and maximum lifetime risk to roughly 9.2×10^{-6}. Although a large percentage reduction could be achieved in the health risks (about 80 to 90 percent), the absolute amount is also small.

Therefore, in light of the extent of control now exhibited by the industry, the small amount of benzene emissions from these sources and the small portion (less than 0.4 percent) of the total benzene emissions from stationary sources that these sources represent, the small leukemia incidence and maximum lifetime risk estimated at current levels, and the small incremental reductions in these health risks achievable with

TABLE 2-2. CURRENT ESTIMATED IMPACTS

Plant	Benzene emissions[a] (Mg/yr)	Leukemia incidence (cases/yr $\times 10^{-4}$)	Maximum lifetime risk ($\times 10^{-6}$)
American Hoechst, LA	0.72	0.093	0.11
American Hoechst, TX	6.25	0.62	0.12
Amoco, TX	15.0	1.4	6.6
ARCO, PA	39.4	15.0	14.0
Cos Mar, LA	17.5	0.44	2.7
Dow, MI	57.3	24.0	140.0
Dow, TX (A)	1.34	0.19	1.5
Dow, TX (B)	36.1	8.3	7.7
El Paso Products, TX	1.85	0.32	0.54
Gulf Oil, LA	9.90	0.24	0.25
Monsanto, TX	19.8	6.3	9.5
Oxirane, TX	1.20	0.36	0.21
Koch, TX	0.58	0.030	0.035
U.S. Steel, TX	0.44	0.19	0.0057
Total	208	57.0	

[a]Revised EPA baseline benzene emission estimates after proposal. Calculated from CMA data package (IV-D-13) and subsequent industry submittals (IV-D-34, IV-D-35, IV-D-36).

combustion control technologies, the Administrator has concluded that benzene emissions from EB/S process vents do not warrant Federal regulatory action under Section 112.

2.1.2 Criteria for Unreasonableness of Residual Risks

Comment: EB/S plants, relative to other stationary sources of benzene emissions, present an insignificant risk to the population. The risk EPA found would be "not unreasonable" after implementation of a national emission standard for benzene emissions from the maleic anhydride industry is almost eight times greater than the current risk from EB/S process vents. Also, leukemia risk from benzene emissions from stationary sources is insignificant because 80 percent of benzene emissions are derived from mobile sources not subject to Section 112 regulation. Therefore, control of EB/S plants represents an inconsistency in EPA's application of risk assessments to the determination of acceptable and unacceptable risks in current proposals for the control of benzene (IV-F-1; IV-F-2; IV-F-3; IV-F-6; IV-D-7; IV-D-10; IV-D-12).

Response: As described in the previous response, the Administrator has reevaluated the health risk posed by this source category and concluded that Federal regulatory action is no longer warranted.

As pointed out by the commenter, mobile sources cannot be regulated under Section 112, and, consequently, no determination has been made concerning the unreasonableness of risk due to exposure to benzene from those sources. However, even if mobile sources could be regulated under Section 112, catalytic converters already being installed seem to be an effective control technology.

2.2 HEALTH AND ENVIRONMENTAL IMPACTS

2.2.1 Estimated Current Emissions and Risks

Comment: According to several commenters, CMA used (1) plant-specific emissions data, (2) local meteorological data, (3) refined population data, (4) a ring-sector approach, which accounts for directional variability in population densities, and (5) the Lamm risk factor to estimate the current risk from benzene emissions from EB/S process vents to be "the same as the 0.00034 risk EPA calculated would exist if the proposed standard had been adopted." Also, EPA has overstated current emissions by a factor of three after correcting for capacity

and existing controls. Therefore, EPA has overestimated both individual and industry-wide emissions; population extent and distribution; and as a consequence, risk from EB/S benzene emissions (IV-F-1; IV-F-2; IV-F-5; IV-F-6; IV-D-10; IV-D-12).

Response: At proposal, environmental impacts were calculated based on data industry supplied from 1972 to 1978 in response to EPA "114" letters (information requests provided for by Section 114 of the Clean Air Act). The responses to the "114" letters provided detailed information from the entire industry. The data submitted were compiled to develop a "typical" EB/S plant that was used to determine impacts. While this model plant did not conform to any particular plant in the industry, it was considered representative for purposes of characterizing the baseline. EPA estimated total nationwide benzene emissions from all EB/S process vents to be 2,100 Mg/yr based on 1978 control levels and actual capacity utilization of nameplate production rates. After publication in the proposal preamble (45 FR 83448), this number was revised to 2,400 Mg/yr to correct miscalculations in the industry-wide total (see Table 2-2).

The industrial source complex (ISC) dispersion model was used to estimate annual average benzene concentrations for distances and directions out to 20 kilometers from the model plant. Houston meteorological data, which best represented weather conditions for most EB/S plants, were used in the dispersion model. Each actual plant was "modeled" by scaling the model plant's emissions to the actual plant's emissions based on known or assumed production capacity and control level. The population residing within 20 kilometers of each EB/S plant was determined from the 1970 Bureau of the Census Master Enumeration District (MED) List. Each plant site was located by latitude and longitude on a grid system having grids of approximately 10 square kilometers. The population was determined from the MED List for each grid block within 20 kilometers of each plant site. Each plant's populations were then coupled with the scaled concentrations derived from the dispersion modeling at the respective distance intervals and the risk factor developed by CAG for the beyond best available technology (BAT) analysis and to describe the standard's health impact. These numbers did not play a role in selection of BAT.

After proposal, CMA supplied detailed data regarding current controls and emissions (IV-D-13; IV-D-34; IV-D-35; IV-D-36). EPA subsequently reanalyzed and revised the baseline environmental impacts on a plant-specific basis using the CMA package and more current information obtained from the industry (IV-D-34; IV-D-35; IV-D-36).

These submittals give vent-by-vent emissions based on measurements or site-specific engineering calculations. In several cases, actual control efficiencies, vent stream measurements, and reduced plant capacities or capacity utilization result in several-fold lower total emissions than reported at proposal. Monsanto has installed a control system that routes nearly all continuous emissions to a boiler (IV-F-2; IV-D-13). Production capacity has been reduced at the American Hoechst, Louisiana, plant, and repairs and new recovery equipment installed since proposal have further reduced baseline emissions at this plant (IV-F-2; IV-D-37). ARCO, Pennsylvania, has significantly reduced production capacity. Most vents at the Oxirane, Texas, plant are controlled before flaring by product recovery devices, giving a greater level of control than assumed by EPA at proposal (IV-F-2; IV-D-13). Likewise, site-specific information on capacities and product recovery at the Dow, Texas, plant have resulted in lower emission estimates that at proposal.

In addition, changes have occurred in the number of operating plants. The ARCO, Texas, ethylbenzene unit has been converted to other uses (IV-F-2), and the Koch (formerly Sun Oil), Texas, styrene unit has been shut down (IV-C-28). Two new plants have come on line, American Hoechst, Texas, and Cos-Mar, Louisiana (a second Cos-Mar plant) (IV-F-2). At the American Hoechst, Texas, plant all process emissions are routed to a boiler, resulting in low benzene emissions (IV-F-2).

Finally, the revised flare efficiency (98 percent compared with 60 percent used at proposal; see Section 2.2.2) results in significantly lower emission estimates in an industry that relies heavily on flaring as a control technique. Plants with significantly reduced, continuous emission estimates because of the revised flare efficiency are: Oxirane, Texas; Gulf, Louisiana; Cos-Mar, Louisiana; El Paso, Texas;

and Dow, Texas. Based on the more recent information and revised analysis, current nationwide benzene emissions from EB/S process vents are estimated to be about 208 Mg/yr (see Table 2-3 and Appendix A).

The ISC dispersion model was used again to compute annual average concentrations at various distances and directions from the plant. However, each plant was modeled individually according to local meteorological data. Geographical coordinates supplied by the plant were then used to match concentrations with corresponding populations on both a distance and directional basis from the plant. Additionally, the CAG unit risk factor was revised based on comments. A more detailed discussion of this methodology can be found in Appendix B of this document, which describes the methodology used to calculate the health impacts. The revised leukemia incidence is estimated to be about 0.0057 cases per year and the maximum lifetime risk about 1.4×10^{-4}.

2.2.2 Flare Control Efficiency

Comment: Three commenters maintained that in the proposed standard, EPA avoids specifying the type of control equipment to be used to limit continuous process emissions. However, the proposed standard was based on the control level attainable when emissions are combusted in a boiler or process heater, and if a plant chooses to control emissions by a method other than combustion in a boiler or process heater, it is required to monitor emissions continuously using a gas chromatograph and flame ionization detector. Because proven technology does not exist for measuring emissions continuously from a flare, the net effect of these requirements is to preclude the use of flares to control continuous process emissions, either as the sole control device or in conjunction with absorbers or condensers. Hydroscience (now IT Enviroscience) (II-B-23) estimated flare efficiency to range from 75 to 98 percent. Small flares (2 to 10 inches in diameter) may have over 99 percent efficiency under optimum conditions. Siegel in Germany tested 1,300 samples to achieve 99 percent efficiency 100 percent of the time. The Battelle study for EPA demonstrated 95 percent

TABLE 2-3. PLANT-BY-PLANT BASELINE EMISSION RATES FOR BENZENE IN 1978 and 1981 (Mg/yr)

Plant/location	1978 Total process emissions[a]	1981 Continuous process emissions[b]	1981 Excess emissions
American Hoechst			
Baton Rouge, LA	320	0.47	0.25
Bayport, TX	0	5.89	0.36
Amoco			
Texas City, TX	26	14.4	0.59
ARCO			
Port Arthur, TX	300	0	0
Kobuta, PA	70	37.0	2.45
Cos-Mar, Inc.			
Carville, LA	420	17.2	0.27
Dow Chemical, USA			
Midland, MI	70	57.1	0.20
Freeport, TX	180	35.8	1.64
El Paso Products			
Odessa, TX	16	1.34	0.51
Gulf Oil			
Donaldsville, LA	180	9.85	0.05
Monsanto Company			
Texas City, TX	320	4.35	15.5
Oxirane			
Channelview, TX	290	1.20	0
Koch (formerly Sun Oil)			
Corpus Christi, TX	15	0.54	0.04
U.S. Steel			
Houston, TX	1	0.42	0.02
Subtotal	2,208	186	22
Plus H_2 separation	110	-	-
Plus excess emissions	113	-	-
TOTAL	2,431	TOTAL	208

[a]Assumes 100 percent capacity utilization and actual plant-by-plant control levels. Derived from proposal BID (EPA-450/3-79-035a).

[b]Includes H_2 separation unit operations. Derived from CMA data package (IV-D-13).

efficiency. Therefore, EPA's decision to preclude the use of flares is arbitrary, capricious, and cannot be sustained (IV-F-1; IV-F-3; IV-D-10.)

Response: At proposal, no conclusive data were available on flare destruction efficiency. Calculations and limited test data showed benzene destruction efficiencies ranging from 60 to 99 percent. These studies included engineering evaluations by Hydroscience, Inc., (II-B-23), calculations based on residence time, limited and unverified test data from a flare manufacturer on a flare burning methane (II-I-29), and EPA in-house estimates. For the purposes of determining impacts, a 60-percent flare efficiency was chosen to enable assessment of "worst-case" emissions from flaring based on limited data and vent stream conditions within the EB/S industry.

Since proposal, more information on flare design and destruction efficiency has become available. In response, EPA has examined recent flare studies to develop a more accurate destruction efficiency estimate for calculating emission impacts from EB/S smokeless flares. The number of flare studies is limited and no data specifically address conditions present within EB/S vent streams. Table 2-4 summarizes four flare studies that provided information on flare gas composition, flow rate, and destruction efficiency. Each study can be found in complete form in the docket (IV-D-17; IV-J-2; IV-J-3; IV-J-7; IV-A-4; IV-A-5). The following discussion reviews the experimental flare systems and operating conditions used in these studies.

Palmer (1972) experimented with a 13-millimeter inside diameter flare head, the tip of which was located 1.2 meter from the ground. Ethylene was flared at 15 to 76 m/s at the exit, with a heat release rate of 0.4 to 2.2 GJ/hr (0.4×10^6 to 2.1×10^6 Btu/hr). Helium was added to the ethylene as a tracer at 1 to 3 volume percent, and the effect of steam injection was investigated in some experiments. Four sets of operating conditions were investigated; destruction efficiency was measured as greater than 99.9 percent for three sets and 97.8 percent for the fourth. The author questioned the validity of the 97.8-percent result due to possible sampling and analytical errors. He recommended further sampling and analytical techniques development before conducting further flare evaluations.

TABLE 2-4. FLARE EMISSIONS STUDIES COMPLETE AS OF OCTOBER 1982

Investigator	Sponsor	Flare tip design	Flared gas	Throughput (GJ/hr)	Flare efficiency (%)
Palmer (1972)	E. I. du Pont	13 mm diameter	Ethylene	0.4 - 2.2	>97.8
Lee and Whipple (1981)	Union Carbide	Discrete holes in 51-mm diameter cap	Propane	0.3	96 - 100
Siegel (1980)	Ph.D. dissertation University of Karlsruhe	Commercial design (700 mm diameter steam)	$\cong$ 50% H_2 plus light hydrocarbons	52 - 188	97 - >99
Howes et al. (1981)	EPA	Commercial design (150 mm diameter air assist)	Propane	46	92.6 - 100
		Commercial design H.P. (3 tips @ 100 mm diameter)	Natural gas	30 (per tip)	>99
McDaniel et al. (1982)	CMA-EPA	Commercial design (460 mm diameter air assist)	Propylene	0.003 - 61	61.9 - 100
		Commercial design (200 mm diameter steam assist)	Propylene	0.01 - 60	68.9 - 100

Sources: Docket items IV-A-4, IV-A-5.

Siegel (1980) made the first comprehensive study of a commercial flare system. He studied burning of refinery gas on a commercial flare head manufactured by Flaregas Company. The flare gases used consisted primarily of hydrogen (45.4 to 69.3 percent by volume) and light paraffins (methane to butane). Traces of H_2S were also present in some runs. The flare was operated from 130 to 2,900 kg/hr of fuel, and the maximum heat release rate was approximately 248 GJ/hr (235 × 10^6 Btu/hr). Combustion efficiency was greater than 99 percent for 1,294 points and greater than 99 percent for all points except one that had a 97-percent efficiency. The author attributed the 97-percent result to excessive steam addition.

Lee and Whipple (1981) studied a bench-scale propane flare. The flare head was 51 millimeters in diameter with one 21-millimeter center hole surrounded by two rings of sixteen 3.2-millimeter holes and two rings of sixteen 4.8-millimeter holes. This configuration had an open area of 57.1 percent. The velocity through the head was approximately 0.9 m/s and the heating rate was 0.3 GJ/hr (0.3 × 10^6 Btu/hr). Effects of steam and crosswind were not investigated in this study. Destruction efficiencies were greater than 99.9 percent for three of four tests. A 97.8-percent result was obtained in the only test where the probe was located off the center line of the flame. The author did not believe this probe location provided a valid gas sample for analysis.

Howes et al. (1981) studied two commerical flare heads at John Zink's flare test facility. The primary purpose of this test (which was sponsored by EPA) was to develop a flare testing procedure. The commercial flare heads were an LH air assisted head and an LRGO (Linear Relief Gas Oxidizer) head manufactured by John Zink Company. The LH flare burned 1,000 kg/hr of commercial propane. The exit gas velocity based on the pipe diameter was 8 m/sec and the firing rate was 46 GJ/hr (44 × 10^6 Btu/hr). The LRGO flare consisted of three burner heads located 0.9 m apart. The three burners combined fired 1,900 kg/hr of natural gas. This corresponds to a firing rate of 88 GJ/hr (83.7 × 10^6 Btu/hr). Steam was not used for either flare, but the LH flare head was assisted by a forced draft fan in some trials. In 4 of 5

tests, combustion efficiency was determined to be greater than 99 percent when sampling height was sufficient to ensure the combustion process was complete. One test resulted in combustion efficiency as low as 92.6 percent when the flare was operated under smoking conditions.

An excellent, detailed review of all four studies was done by Payne et al. in January 1982, and a summary of the studies is given in Table 2-4. A fifth study, by McDaniel et al. 1982, determined the influence on flare performance of mixing, flare gas energy content and gas flow velocity. Steam-assisted and air-assisted flares were tested at the John Zink facility using the procedures developed by Howes. The test was sponsored by CMA with the cooperation and support of EPA. All tests were with an 80 percent propylene, 20 percent propane mixture diluted as required with nitrogen to give different flare gas energy contents. This was the first work which determined flare efficiencies at a variety of "nonideal" conditions where lower efficiencies had been predicted. All previous tests were of flares which burned gases which were very easily combustible and did not tend to soot. This was also the first test which used the sampling and chemical analysis methods developed for EPA by Howes.

The steam assisted flare was tested with exit flow velocities up to 19 m/sec, with gas heat contents from 11.0 to 81.3 MJ/stdm^3 (294 to 2,183 Btu/standard cubic foot [scf]) and with steam to gas (weight) ratios varying from 0 (no steam) to 6.86. Flares without assist were tested down to 7.15 MJ/stdm^3 (192 Btu/scf). All of these tests, except for those with very high steam to gas ratios, showed combustion efficiencies of over 98 percent. Flares with high steam to gas ratios (about 10 times more steam than that required for smokeless operation) had lower efficiencies (69 to 82 percent) when combusting 81.3 MJ/stdm^3 (2,183 Btu/scf) of gas.

The air assisted flare was tested with flow velocities up to 66.4 m/s and with gas heat contents from 3.1 to 81.3 MJ/stdm^3 (83 to 2,183 Btu/scf). Tests at 10.5 MJ/stdm^3 (282 Btu/scf) and above gave over 98 percent efficiency. Tests at 6.26 MJ/stdm^3 (168 Btu/scf) gave 55 percent efficiency.

After consideration of the results of these five tests, EPA has concluded that 98 percent combustion efficiency can be achieved by steam-assisted, smokeless flares with exit flow velocities less than 18 m/s and flared gas heat contents of at least 11.2 MJ/stdm^3 (300 Btu/scf) and by flares operated without assist with exit flow velocities less than 18 m/sec and flared gas heat contents of at least 7.45 MJ/stdm^3 (200 Btu/scf). Ninety-eight percent combustion efficiency can also be achieved by air-assisted, smokeless flares with flared-gas heat contents over 11.2 MJ/stdm^3 (300 Btu/scf) and with exit flow velocities below a calculated value dependent upon the flared gas heat content. These are the only conditions for which EPA has data supporting 98 percent emission reduction by flares. Flares are not normally operated at the very high steam to gas ratios that resulted in low efficiency in some tests because steam is expensive and operators make every effort to keep steam consumption low. Flares with high steam rates are also noisy and may be a neighborhood nuisance.

Consequently, since the 98-percent value is considered to be a reasonable estimate of flare efficiency for EB/S plants based on the limited data available in the literature to date, EPA assigned a 98-percent destruction efficiency to smokeless flares within the EB/S industry in order to calculate impacts. This efficiency estimate does not suggest that all flares used in the EB/S industry are only 98 percent efficient but represents a reasonable level of flare efficiencies at EB/S plants in order to estimate emissions.

APPENDIX A

EMISSION DATA AND ENVIRONMENTAL IMPACTS

APPENDIX A

EMISSION DATA AND ENVIRONMENTAL IMPACTS

A.1 INTRODUCTION

The purpose of this appendix is to show how the baseline benzene emissions were developed. An explanation of assumptions used in emission estimations accompanies the discussion. Subsection A.2 discusses the assumptions used in determining baseline benzene emissions. This subsection also summarizes the benzene emission data used to determine the environmental impacts of these emissions.

A.2 ORIGINAL AND REVISED BASELINE BENZENE EMISSIONS

A.2.1 U.S. Environmental Protection Agency (EPA) Baseline Benzene Emission Estimates at Proposal

The emission rates presented at proposal were derived from an integrated and totally uncontrolled model EB/S plant. Emission rates were first estimated assuming a constant nameplate production capacity, 100 percent capacity utilization, and no control for four process emission sources: (1) alkylation reactor vents; (2) atmospheric/pressure column vents; (3) vacuum column vents; and (4) H_2 separation vents. Variations in emissions potential among plants were averaged, assuming a constant capacity and no control, to yield a "typical" emission rate for each emission source in a plant. Emission rates for the four sources described above were scaled to actual plant control levels, actual capacity use, and 8,000 operating hr/yr to derive plant-by-plant emission estimates. In plants where only ethylbenzene or styrene was produced, the model plant's corresponding process vents were used to estimate the contribution of that source.

The plant-by-plant emission controls for continuous process vents used at proposal are listed in Table A-1. At proposal, these

TABLE A-1. EMISSIONS CONTROLS PRESENT ON EB/S PLANTS AT PROPOSAL, LISTED BY VENT TYPE[a]

Plant/location	Emission controls on various vent types[b]			
	Alkylation reactor area vents	Atmospheric/pressure column vents	Benzene/toluene column vents	Other vacuum column vents
American Hoechst, LA "A"	LD FLR	No C	No C	No C
American Hoechst, TX "B"	RC/RS to SD FLR	RC/RS to SD FLR	SD FLR via NGE	SD FLR via NGE
Amoco, TX	RC to BLR via Cmp	BLR	RC to BLR via Cmp	No C
ARCO, PA	-	-	No C	No C
ARCO, TX	No C	No C	-	-
Cos-Mar, LA	LD FLR	LD FLR	RC	No C
Dow Chemical, TX "A"	No C	SD FLR	No C	No C
Dow Chemical, TX "B"	BLR	BLR	RS to SD FLR	RS to SD FLR
Dow Chemical, MI	-	-	No C	No C
El Paso Products, TX	BLR	BLR	SD FLR	SD FLR
Gulf, LA	LD FLR	LD FLR	RC	RC
Monsanto, TX	BLR	RC to BLR via Cmp	RC to BLR via Cmp	RC to BLR via Cmp
Oxirane, TX	SD FLR	SD FLR	-	-
Sun Oil, TX	BLR	BLR	No C	No C
U.S. Steel, TX	-	BLR via NGE	BLR via NGE	BLR via NGE

[a]Information from EB/S Docket Item No. II-B-18.

[b]Control device key:
FLR - Flare (60% efficiency)
BLR - Boiler (99% efficiency)
RC - Refrigerated condenser (85% efficiency)
RS - Refrigerated scrubber (85% efficiency)
Cmp - Compressor
NGE - Natural gas ejector
SD - Small diameter
LD - Large diameter
No C - No control
- Denotes no vents of this type in that particular plant.

data (II-B-18) were derived from EPA 114 letters, plant visits, and telephone calls. The estimation of plant-by-plant emissions for each vent involved multiplication of plant nameplate capacity by the sum of the appropriate emission factors times the specific control achieved. The estimation of emissions from all plants for a given vent involved multiplication of the emission factor by the sum of each plant's nameplate capacity times the fraction of control for the vent at that plant. The estimation of emissions from the hydrogen separation vent involved multiplication of the entire industry nameplate capacity by the emission factor times the fraction of control. This was applicable because 99 percent control was assumed for the entire industry. The data used to estimate emissions are listed in Table A-2.

A.2.1.1 Continuous Emission Estimation--Plant-By-Plant Emissions. The following example shows how emissions from the American Hoechst "B," Bayport, Texas, facility were estimated. Plant-by-plant emissions were estimated through the following calculations.

The nameplate capacity was multiplied by the sum of the products of the emission factor times (1-[fraction of control]) for each vent type to determine a plant's emissions. For the American Hoechst "B" plant, the calculation would be as follows:

$$(0.67) \times (450 \times 10^3 \text{ Mg/yr}) \times [0.3 \text{ Mg}/10^3 \text{ Mg} \times (1-0.6) \times (1-0.85) + 1.2 \text{ Mg}/10^3 \text{ Mg} \times (1-0.6) \times (1-0.85) + 0.3 \text{ Mg}/10^3 \text{ Mg} \times (1-0.6) + 0.05 \text{ Mg}/10^3 \text{ Mg} \times (1-0.6)] = 70 \text{ Mg/yr} ,$$

where

$(0.67) \times (450 \times 10^3)$ = utilized fraction of nameplate production capacity

$(0.3/10^3) \times (1-0.6) \times (1-0.85)$ = uncontrolled emission factor from alkylation reactor area vents

$(1.2/10^3) \times (1-0.6) \times (1-0.85)$ = uncontrolled emission factor from atmospheric/pressure column vents

$(0.3/10^3) \times (1-0.6)$ = uncontrolled emission factor from benzene/toluene column vents

$(0.05/10^3) \times (1-0.6)$ = uncontrolled emission factor from other vacuum column vents.

TABLE A-2. NAMEPLATE CAPACITIES, EMISSIONS FACTORS, AND PERCENT CONTROL USED AS THE BASIS FOR PLANT-BY-PLANT BENZENE EMISSIONS ESTIMATED AT PROPOSAL[a]

Plant/location	Capacity[c] (10^3 Mg/yr)	Percent control by vent type (emissions factor[b])				Total emissions (Mg/yr)[d]
		Alkylation reactor area vents (0.3)	Atmospheric/pressure column vents (1.2)	Benzene/toluene column vents (0.3)	Other vacuum column vents (0.05)	
American Hoechst, LA "A"	(0.33)(450)	0.6	0	0	0	250
American Hoechst, TX "B"	(0.67)(450)	(0.85)(0.6)	(0.85)(0.6)	0.6	0.6	70
Amoco, TX	375	0.99	0.99	0.99	0	26
ARCO, PA	200	-	-	0.	0	70
ARCO, TX	(1.15)(227)	0	0	-	-	300
Cos-Mar, LA	600	0.6	0.6	0.85	0	420
Dow Chemical, TX "A"	(0.2) (700)	0	0.6	0	0	160
Dow Chemical, TX "B"	(0.8) (700)	0.99	0.99	(0.85)(0.6)	(0.85)(0.6)	20
Dow Chemical, MI	200	-	-	0	0	70
El Paso Products, TX	100	0.99	0.99	0.6	0.6	16
Gulf, LA	275	0.6	0.6	0.85	0.85	180
Monsanto, TX	600	0	0.85	0.85	0.85	320
Oxirane, TX	550	0.6	0.6	-	-	290
Sun Oil, TX	40	0.99	0.99	0	0	15
U.S. Steel, TX	54	-	-	0.99	0.99	<1
Total emissions per vent type (Mg/yr)		375	1,380	425	100	2,208
Plus H_2 separation[e]						110
Plus excess emissions[f]						113
Total emissions						2,451

[a]Information from EB/S Docket Item No. II-B-18.

[b]Emissions factors are in Mg/10^3 Mg.

[c]Capacity presented in utilization fraction times nameplate capacity; where nameplate capacity alone is given, utilization fraction equals 1.0.

[d]Assumes 8,000 hr/yr of operation.

[e]Assumes uncontrolled emissions factor of 2.7 Mg/10^3 Mg, nameplate capacity and 99% control for H_2 separation continuous vents at all plants (II-B-18)

[f]Excess emissions from the proposal background information document (BID) (EPA-450/3-37-035a; p. AA3) based on nameplate production capacity and existing controls.

A.2.1.2 Continuous Emission Estimation--Industry-Wide Emissions For a Given Vent. The following example shows how industry-wide emissions from the atmospheric/pressure column vents were estimated. Each vent's industry-wide emissions were estimated through the following calculations.

To determine industry-wide emissions for a given vent, multiply the emission factor by the summed products of the plant capacity times (1-[fraction of control]) for each vent of that type at each plant. For the atmospheric/pressure column vents, the calculation would be as follows:

$$1.2 \times [0.33 \times (450) + 0.67 \times (450) \times (1-0.6) \times (1-0.85) + (375) \times (1-0.99) + (1.15) \times (227) + 600 \times (1-0.6) + 0.2 \times (700) \times (1-0.6) + 0.8 \times (700) \times (1-0.99) + 100 \times (1-0.99) + 275 \times (1-0.6) + 600 \times (1-0.85) + 550 \times (1-0.6) + 40 \times (1-0.99)] = 1{,}380 \text{ Mg/yr},$$

where

1.2 = emission factor for atmospheric/pressure column vents (A/P vents) in $Mg/10^3$ Mg

$0.33 \times (450) + 0.67 \times (450) \times (1-0.6) \times (1-0.85)$ = A/P vent "uncontrolled capacities" from American Hoechst, LA, "A" and "B" plants, respectively, 10^3 Mg/yr (units given as an example for all plants)

$375 \times (1-0.99)$ = A/P vent "uncontrolled capacity" from Amoco, TX

$227 \times (1.15)$ = A/P vent "uncontrolled capacity" from ARCO, TX

$600 \times (1-0.6)$ = A/P vents "uncontrolled capacity" from Cos-Mar, LA

$0.2 \times (700) \times (1-0.6) + 0.8 \times (700) \times (1-0.99)$ = A/P vents "uncontrolled capacities" from Dow Chemical, TX, "A" and "B" Plants

$100 \times (1-0.99)$ = A/P vent "uncontrolled capacity" from El Paso, TX

$275 \times (1-0.6)$ = A/P vent "uncontrolled capacity" from Gulf, LA

$600 \times (1-0.85)$ = A/P vent "uncontrolled capacity" from Monsanto, TX

$550 \times (1-0.6)$ = A/P vent "uncontrolled capacity" from Oxirane, TX

$40 \times (1-0.99)$ = A/P vent "uncontrolled capacity" from Sun Oil, TX.

A.2.1.3 Continuous Emission Estimation--Industry-Wide Emissions From the Hydrogen Separation Vent. The following calculation shows how industry-wide emissions from the hydrogen separation column vent were estimated. Because specific plant-by-plant data were unavailable at proposal, the entire industry nameplate capacity was multiplied by the emission factor for the hydrogen separation vent times (1-[fraction of control]) to estimate emissions due to hydrogen separation vents. The calculation would be as follows:

$$4{,}000 \times 10^3 \text{ Mg/yr } [2.7 \text{ Mg}/10^3\text{Mg} \times (1\text{-}0.99)] = 110 \text{ Mg/yr},$$

where

4,000 = industry nameplate capacity

2.7 = emission factor for hydrogen separation vent

(1-0.99) = uncontrolled percent.

A.2.1.4 Excess Emission Estimation. Excess emissions can occur during (1) plant startup, (2) plant shutdown, and (3) as a result of either process or air pollution control equipment failure. A comprehensive discussion of the sources and amounts of excess emissions is contained in the proposal BID (EPA-450/3-79-035a; p. AA3). In summary, the proposal BID explains that at proposal, baseline excess emissions from EB/S facilities totaled about 133 Mg/yr based on 100 percent nameplate production capacity and existing controls.

A.2.2 Revised U.S. Environmental Protection Agency (EPA) Baseline Benzene Emission Estimates

Since proposal, the Chemical Manufacturer's Association (CMA) commented that EPA's benzene emission data were overestimated because the EPA estimates did not consider plant-specific production and control levels. CMA and individual companies supplied plant-specific emission data that included emission sources, benzene emission rates in grams per second for each emission source, control device efficiency assumptions, and actual operating capacities for continuous and excess emissions based on actual operating hours per year (IV-D-13, IV-D-34, IV-D-35, IV-D-36). The grams-per-second benzene emission flow rate was calculated by CMA from actual annual benzene flow rates averaged over 8,760 hr/yr.

EPA used the CMA data to revise benzene emission estimates from the EB/S industry. EPA converted the benzene emission rate estimates presented in the industry submittals from grams per second to megagrams per year assuming 8,760 hr/yr. Revised EPA estimates, in contrast to original estimates, reflect actual vent-by-vent emission rates, capacity utilization, and control levels, and assume 8,760 operating hr/yr. EPA also recalculated emission estimates from flares by revising the flare destruction efficiency rating of 60 percent, which CMA used to estimate emissions from flares, to 98 percent (see Response 2.2.2 of this document). First, EPA calculated uncontrolled emissions from the CMA emission estimates at 60 percent control. Second, EPA multiplied the uncontrolled emission rate by 0.02 (=1-.98) to estimate emissions at 98 percent control. Emission estimates for each emission source were summed to estimate a plant's total emissions, and plant-by-plant emission estimates were summed to estimate industry-wide emissions. It should be noted that according to the CMA data package (IV-D-13), the EB/S industry currently is not operating at peak capacity and exhibits a 97-percent overall control level (see Table A-3).

Based on the data supplied by industry and the assumptions previously noted, EPA reestimated total benzene emissions from the EB/S industry to be 208 Mg/yr. Of this total, 186 Mg/yr were estimated to result from continuous process emission sources and about 22 Mg/yr were estimated to result from excess process emission sources (see Table A-4).

TABLE A-3. CAPACITY UTILIZATION, PERCENT CONTROL, AND EB/S PLANTS IN OPERATION AT BASELINE[a]

Plant/location	Capacity utilization (%)	Overall control (%)
American Hoechst, LA	60	99
American Hoechst, TX	100	99
Amoco, TX	90	99
ARCO, PA	45	65
Cos-Mar, LA	100	99
Dow Chemical, TX	100	95
Dow Chemical, MI	100	71
El Paso Products, TX	100	98
Gulf, LA	100	99
Monsanto, TX	100	95
Oxirane, TX	100	98
Koch, TX	100	98
U.S. Steel, TX	100	99
Industry-wide	90	97

[a]Actual production and control levels from CMA data package (IV-D-13) and subsequent industry submittals (IV-D-34, IV-D-35, IV-D-36) used by EPA in estimating current plant-by-plant benzene emissions. Operating hours per year assumed to be 8,760.

TABLE A-4. REVISED EPA BASELINE BENZENE EMISSION ESTIMATES[a]

Plant/location	Continuous emissions (Mg/yr)	Excess emissions (Mg/yr)
American Hoechst, LA	0.47	0.25
American Hoechst, TX	5.89	0.36
Amoco, TX	14.4	0.59
ARCO, PA	37.0	2.45
Cos-Mar, LA	17.2	0.27
Dow Chemical, TX	35.8	1.64
Dow Chemical, MI	57.1	0.20
El Paso Products, TX	1.34	0.51
Gulf, LA	9.85	0.05
Monsanto, TX	4.35	15.5
Oxirane, TX	1.20	0
Koch, TX	0.54	0.04
U.S. Steel, TX	0.42	0.02
SUBTOTAL	186	22
TOTAL	208	

[a]Revised EPA baseline benzene emissions estimates after proposal. Calculated from CMA data package (IV-D-13) and subsequent industry submittals (IV-D-34, IV-D-35, IV-D-36).

APPENDIX B

METHODOLOGY FOR ESTIMATING LEUKEMIA INCIDENCE AND MAXIMUM LIFETIME RISK FROM EXPOSURE TO BENZENE EMISSIONS FROM ETHYLBENZENE/STYRENE PROCESS VENTS

APPENDIX B
METHODOLOGY FOR ESTIMATING LEUKEMIA INCIDENCE AND MAXIMUM LIFETIME RISK FROM EXPOSURE TO BENZENE EMISSIONS FROM ETHYLBENZENE/STYRENE PROCESS VENTS

B.1 INTRODUCTION

The purpose of this appendix is to describe the methodology and to provide the information used to estimate leukemia incidence and maximum lifetime risk from population exposure to benzene emissions from ethylbenzene/styrene (EB/S) process vents. The methodology consists of four major components: estimating annual average concentration patterns of benzene in the region surrounding each plant, estimating the population associated with each computed concentration, computing exposure by summing the products of the concentrations and associated populations, and estimating annual leukemia incidence and maximum lifetime risk from exposure and concentration estimates. Due to the assumptions made in each of these four steps of the methodology, there is considerable uncertainty associated with the lifetime individual risk and leukemia incidence numbers calculated in this appendix. These uncertainties are explained in Section B.6 of this appendix.

B.2 ATMOSPHERIC DISPERSION MODELING

The long-term version of the Industrial Source Complex (ISCLT) dispersion model[1] was used to estimate annual average benzene concentrations in the vicinity of 14 EB/S plants. (For the purpose of this analysis the "A" and "B" units of the Dow, Texas, plant are assumed to be two plants.)

STAR summaries are the principal meteorological input to the ISCLT Model. A STAR summary is a tabulation of the joint frequency of occurrence of wind-speed and wind-direction categories, classified according to the Pasquill stability categories. For this modeling analysis, 5 consecutive years of wind and stability data were used to develop the STAR summaries. Hourly data were used where available, otherwise data taken once every 3 hours were used.

The ISCLT Model also requires the input of ambient temperatures and mixing heights by stability category. National Weather Service stations were used to determine the average annual mean, maximum and minimum daily temperature

was assigned to the A, B, and C stability categories; the average annual mean daily temperature was assigned to the D stability category; and the average annual minimum daily temperature was assigned to the E and F stability categories. Mixing height input data to the ISCLT Model was calculated by averaging hourly CRSTER Model meteorological preprocessor mixing height data by stability category. Rural mixing heights and stability categories were used for all plants, except the USS plant in Houston, Texas where urban mixing heights and stability categories were used.

The receptor grid consists of ten downwind distances located along 16 radials. The radials are separated by 22.5 degree intervals beginning with 0 degrees and proceeding clockwise to 337.5 degrees. The ten downwind distances for each radial are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0 and 20.0 kilometers. The x=0, y=0 location at each plant was placed at the center of the recepter grid.

The ISCLT output for all plants modeled, consisting of annual concentration estimates at all 160 receptors, is contained in the docket (Docket item IV-J-10). ISCLT dispersion model concentration estimates have been found to be within a factor of two of measured concentrations in most tests.[2]

B.3 POPULATION AROUND ETHYLBENZENE/STYRENE PLANTS

The human exposure model (HEM)[3] was used to estimate the population that resides in the vicinity of each receptor coordinate surrounding each EB/S plant. A slightly modified version of the "Master Enumeration District List-- Extended" (MED-X) data base is contained in the HEM and used for population pattern estimation. This data base is broken down into enumeration district/block group (ED/BG) values. MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the United States (50 States plus the District of Columbia). For human exposure estimations, MED-X has been reduced from its complete form (including descriptive and summary data) to produce a randomly accessible computer file of the data necessary for the estimation. A separate file of county-level growth factors, based on the 1978 estimates of 1970 to 1980 growth factor at the county level, has also been created for use in estimating 1980 population figures for each ED/BG. The population "at risk" to benzene exposure was considered to be persons residing within 20 km of EB/S plants. The population around each plant was identified by specifying the geographical coordinates of that plant.

B.4 POPULATION EXPOSURE METHODOLOGY

B.4.1 Exposure Methodology

The plant's geographical coordinates and the concentration patterns computed by the ISCLT were used as input to the HEM. (The HEM also has its own atmospheric dispersion model. However, the HEM dispersion model, still under development, is not as detailed as the ISCLT and less well suited for multiple point emission sources.)

For each receptor coordinate, the concentration of benzene estimated by the ISCLT and the population estimated by the HEM to be exposed to that particular concentration are identified. The HEM multiplies these two numbers to produce population exposure estimates and sums these products for each plant. A two-level scheme has been adopted in order to pair concentrations and populations prior to the computation of exposure. The two-level approach is used because the concentrations are defined on a radius-azimuth (polar) grid pattern with nonuniform spacing. At small radii, the grid cells are much smaller than ED/BG's; at large radii, the grid cells are much larger than ED/BG's. The area surrounding the source is divided into two regions, and each ED/BG is classified by the region in which its centroid lies. Population exposure is calculated differently for the ED/BG's located within each region.

For ED/BG centroids located between 0.1 km and 2.8 km from the emission source, populations are divided between neighboring concentration grid points. There are 96 (6 x 16) polar grid points within this range. Each grid point has a polar sector defined by two concentric arcs and two wind direction radials. Each of these grid points is assigned to the nearest ED/BG centroid identified from MED-X. The population associated with the ED/BG centroid is then divided among all concentration grid points assigned to it. The exact land area within each polar sector is considered in the apportionment.

For population centroids between 2.8 km and 20 km from the source, a concentration grid cell, the area approximating a rectangular shape bounded by four receptors, is much larger than the area of a typical ED/BG (usually 1 km in diameter). Since there is a linear relationship between the logarithm of concentration and the logarithm of distance for receptors more than 2 km from the source, the entire population of the ED/BG is assumed to be exposed to the concentration that is geometrically interpolated radially and arithmetically interpolated azimuthally from the four receptors bounding the grid cell. Concentration estimates for 80 (5 x 16) grid cell receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of 16 wind directions are used as reference points for this interpolation.

In summary, two approaches are used to arrive at coincident concentration/population data points. For the 96 concentration points within 2.8 km of the source, the pairing occurs at the polar grid points using an apportionment of ED/BG population by land area. For the remaining portions of the grid, pairing occurs at the ED/BG centroids themselves, through the use of log-log and linear interpolation. (For a more detailed discussion of the methodology used to estimate exposure see Reference 3.)

B.4.2 Total Exposure

Total exposure (persons-$\mu g/m^3$) is the sum of all multiplied pairs of concentration-population computed by the previously discussed methodology:

$$\text{Total exposure} = \sum_{i=1}^{N} (P_i C_i) \qquad (1)$$

where

P_i = population associated with point i,

C_i = annual average benzene concentration at point i, and

N = total number of polar grid points between 0 and 2.8 km and ED/BG centroids between 2.8 and 20 km.

The computed total exposure is then used with the unit risk factor to estimate leukemia incidence and maximum lifetime individual risk. This methodology is described in the following sections. (Note. "Exposure" as used here is the same as "dosage" in the computer printout, docket item IV-J-10).

B.4.3 Unit Risk Factor

The unit risk factor (URF) for benzene is 9.9×10^{-8} (leukemia cases per year)/($\mu g/m^3$ -person years), as calculated by EPA's Carcinogen Assessment Group (CAG). This factor is slightly lower than the factor derived by CAG at proposal. Arguments have been advanced that, in addition to the conservative nature of the model used, the assumptions made by EPA (CAG) in the derivation of a unit leukemia risk factor for benzene represented "serious misinterpretation" of the underlying epidemiological evidence. Among the specific criticisms are: CAG (1) inappropriately included in its evaluation of the Infante et al. study two cases of leukemia from outside the cohort, inappropriately excluded a population of workers that had been exposed to benzene, and

improperly assumed that exposure levels were comparable with prevailing occupational standards; (2) accepted, in the Aksoy et al. studies, an unreasonable undercount of the background leukemia incidence in rural Turkey, made a false adjustement of age, and under-estimated the exposure duration; and (3) included the Ott et al. study in the analysis despite a lack of statistical significance.

EPA has reexamined and reevaluated each of the three studies. In summary, EPA concluded that one case of leukemia was inappropriately included from the Infante et al. study in computing the original unit risk factor. Additionally, EPA reaffirmed its decision to exclude dry-side workers from that study in developing the risk factor. The Agency agrees that the Aksoy et al. study was adjusted improperly for age; however, the exposures and durations of exposures are still considered reasonable estimates. The Ott et al. study was not eliminated from the risk assessment because the findings meet the test of statistical significance and because it provides the best documented exposure data available from the three epidemiological studies.

Based on these findings, the unit risk factor (the probability of an individual contracting leukemia after a lifetime of exposure to a benzene concentration of one part benzene per million parts air) was recalculated. The revised estimate resulted in a reduction of about 7 percent from the original estimate of the geometric mean, from a probability of leukemia of $0.024/ppm^4$ to a probability of leukemia of 0.022/ppm.

B.4.4 Calculation of Estimated Annual Leukemia Incidence

The annual leukemia incidence associated with a given plant is the product of the total exposure around that plant in $\mu g/m^3$-persons and the unit risk factor, 9.9×10^{-8}. Thus,

$$\text{Annual leukemia incidence} = (\text{total exposure}) \times (\text{unit risk factor}), \qquad (2)$$

where total exposure is calculated according to Equation 1.

B.4.5 Calculation of Maximum Lifetime Risk

The populations in areas surrounding EB/S plants have various risk levels of leukemia incidence from exposure to benzene emissions. Using the maximum annual average concentration of benzene to which any person is exposed, it is

possible to calculate the maximum lifetime risk of leukemia (lifetime probability of leukemia to persons exposed to the highest concentration of benzene) attributable to benzene emissions using the following equation:

$$\text{Maximum lifetime risk} = C_{i,max} \times (URF) \times 70, \quad (3)$$

where

$C_{i,max}$ = the maximum annual average concentration at any receptor location where exposed persons reside,

URF = the unit risk factor, 9.9×10^{-8} and

70 years = average individual's life span.

B.5 LEUKEMIA INCIDENCE AND MAXIMUM LIFETIME RISK

B.5.1 Input Data, Assumptions, and Methodology

Population exposures were computed for the current level of control for each plant in order to estimate the baseline leukemia incidence and maximum lifetime risk.

The plants and their locations are shown in Table B-1. The emission rates and other dispersion model inputs are shown in Table B-2. Total exposure and maximum annual average concentrations for each plant are shown in Table B-3.

After population exposure at baseline was computed, leukemia incidence estimates were made. Population exposure was multiplied by the CAG leukemia risk factor of 9.9×10^{-8} to estimate the annual leukemia incidence for each plant.

Maximum lifetime risk for a given plant is found by multiplying the maximum annual average concentration by the unit risk factor of 9.9×10^{-8} times 70 years (to obtain a lifetime estimate). The maximum lifetime risk for the industry is that due to the plant with the highest maximum lifetime risk in the industry.

TABLE B-1. EB/S PLANTS AND LOCATIONS

Plant	Location	Latitude	Longitude
American Hoechst	Baton Rouge, LA	30°33'08"	91°12'40"
American Hoechst	Bayport, TX	29°36'10"	95°01'15"
Amoco	Texas City, TX	29°21'58"	94°55'45"
ARCO	Kobuta, PA	40°39'21"	80°21'20"
Cos Mar	Carville, LA	30°14'16"	91°04'09"
Dow	Midland, MI	43°35'42"	84°12'18"
Dow (A)	Freeport, TX	28°57'15"	95°19'08"
Dow (B)	Freeport, TX	28°59'17"	95°24'09"
El Paso Products	Odessa, TX	31°49'27"	102°19'29"
Gulf Oil	Donaldsonville, LA	30°05'44"	90°55'19"
Monsanto	Texas City, TX	29°22'44"	94°53'40"
Oxirane	Channelview, TX	29°49'07"	95°06'07"
Sun Oil	Corpus Christi, TX	27°49'57"	97°31'38"
U.S. Steel	Houston, TX	29°42'18"	95°15'06"

TABLE B-2. EMISSIONS DATA FOR AIR MODELING: BASELINE

Plant/ Location	Emission Type	Control Device	Benzene Rate (g/s)	Temp. (°K)	Location (m) (x)	(y)	Stack Height (m)	Stack Dia. (m)	Stack Velocity (m/s)	Emission Direction	Plant Coordinates Lat.	Long.	Temp. (°C)	Pressure (millibars)
Am. Ho./LA	C	Absorber	0.002	300	33	0	12.8	0.07	3.7	U	30°33'08"	91°12'40"	20	1,015
	C	Superheater	0.002	561	(28)	46	32.0	1.67	3.4	U				
	C	Superheater	0.011	561	(28)	30	50.3	2.84	5.5	U				
	E	Flare	0.008	977	(486)	(84)	2.13	2.1	10.0	U				
Am. Ho./TX	C	Boiler	0.0388	455	24	(7)	27.1	1.8	10.4	U	29°36'10"	95°01'15"	21	1,016
	C	Boiler	0.0388	455	42	(7)	27.1	1.8	10.4	U				
	C	Boiler	0.0388	455	62	(7)	27.1	1.8	10.4	U				
	C	Superheater	0.0705	460	(84)	13	71.5	3.4	4.0	U				
	E	Flare	0.0115	1,366	30	(107)	82.3	1.06	7.9	U				
Amoco/TX	C	None	0.0016	330	(69)	(1)	4.88	0.052	1.72	U	29°21'58"	94°55'45"	21	1,017
	C	None	0.0006	330	(103)	(6)	4.88	0.052	0.57	U				
	C	Superheater	0.2854	606	0	0	53.3	2.85	5.9	U				
	C	Furnace	0.1674	611	15	(2)	31.1	1.98	7.22	U				
	E	Flare	0.0029	823	(292)	121	83.3	0.59	64.0	U				
	E	None	0.0158	330	(111)	(31)	4.88	0.052	4.80	U				
ARCO/PA	C	None	1.15	318	0	0	25.9	0.30	0.135	D	40°39'21"	80°21'20"	10	990
	C	Superheater	0.0236	530	23	(21)	30.4	1.22	3.13	U				
	E	None	0.0778	318	14	(30)	18.23	0.1	0.1	U				
Cos-Mar/LA	C	Condenser	0.0158	280	(73)	(158)	12.2	0.05	0.1	D	30°14'16"	91°04'09"	20	1,016
	C	Condenser	0.0158	280	61	(158)	9.1	0.05	0.1	D				
	C	Flare	0.0111	1,144	35	11	53.3	0.4063	0.0014	U				
	C	Flare	0.0129	1,144	(55)	29	53.3	0.4063	0.0015	U				
	C	Superheater	0.225	569	62	(253)	53.3	2.83	4.51	U				
	C	Superheater	0.262	577	(27)	(217)	54.9	3.25	4.11	U				
	C	None	0.0015	318	(22)	(157)	11.8	0.05	0.1	D				
	C	None	0.0015	318	64	(160)	11.8	0.05	0.1	D				
	E	Flare	0.004	1,144	35	11	53.3	0.4063	22.4	U				
	E	Flare	0.0047	1,144	(55)	29	53.3	0.4063	26.1	U				

TABLE B-2. EMISSIONS DATA FOR AIR MODELING: BASELINE (Continued)

Plant/ Location	Emission Type	Control Device	Benzene Rate (g/s)	Temp. (°K)	Location (m) (x)	(y)	Stack Height (m)	Stack Dia. (m)	Stack Velocity (m/s)	Emission Direction	Plant Coordinates Lat.	Long.	Temp. (°C)	Pressure (millibars)
Dow/MI	C	Condenser	1.70	358	0	0	14.9	0.05	0.52	U	43°35'42"	84°12'18"	8	996
	C	Stripper	0.0633	316	95	41	0.3	0.055	0.1	D				
	C	Furnace	0.0230	422	107	91	12.7	0.430	65.2	U				
	C	Furnace	0.0230	422	107	143	12.7	0.430	65.2	U				
	C	Condenser	0.0003	300	1	0	0.3	0.001	0.1	D				
	E	None	0.0032	314	106	58	13.5	0.200	33.0	U				
	E	None	0.0032	314	106	108	13.5	0.200	33.0	U				
El Paso/TX	C	Oil heater	0.0012	789	(90)	(50)	15.24	1.37	28.8	U	31°49'27"	102°19'29"	18	914
	C	Superheater	0.0086	444	50	(20)	57.9	2.05	21.5	U				
	C	Flare	0.0328	823	200	80	20	0.102	20.2	U				
	E	Flare	0.0161	823	(460)	(620)	37	0.760	0.73	U				
Dow/TX/B	C	Furnace	0.0014	433	(1,261)	213	55.0	3.66	6.30	U	28°59'17"	95°24'09"	21	1,016
	C	Boiler	0.0072	433	(1,278)	248	18.0	1.68	7.80	U				
	C	Boiler	0.0072	433	(1,283)	238	18.0	1.68	7.80	U				
	C	Boiler	0.0072	433	(1,286)	228	18.0	1.68	7.80	U				
	C	None	0.0032	373	(1,013)	267	9.0	0.300	0.300	U				
	C	Flare	0.00001	823	(1,089)	109	27.6	0.08	0.1	U				
	E	None	0.0066	373	(1,186)	226	21.0	2.13	8.0	U				
	E	None	0.021	294	(1,186)	226	21.0	2.13	1.3	U				
	E	None	0.001	373	(1,101)	128	21.0	0.15	118	U				
	C	Scrubber	0.4603	294	(50)	(110)	29.0	0.076	0.06	U				
	C	Scrubber	0.4603	294	80	(40)	29.0	0.076	0.06	U				
	C	Flare	0.0040	823	(135)	(50)	27.1	0.482	0.1	U				
	C	Flare	0.0040	823	40	(115)	27.1	0.482	0.1	U				
	C	Flare	0.0040	823	415	(235)	27.1	0.482	0.1	U				
	C	Furnace	0.0978	464	(45)	50	29.5	1.5	15.9	U				
	C	Furnace	0.0374	503	95	(20)	18.3	1.2	8.50	U				
	C	Furnace	0.0027	673	98	(2)	16.8	1.4	0.81	U				
	C	Furnace	0.0027	673	102	(5)	16.8	1.4	0.81	U				
	C	Furnace	0.0027	673	116	(8)	16.8	1.4	0.81	U				
	C	Furnace	0.0027	673	125	(11)	16.8	1.4	0.81	U				
	C	Furnace	0.0043	623	85	2	20.4	0.900	1.60	U				
	C	Furnace	0.0043	623	80	10	20.4	0.900	1.60	U				
	E	None	0.0023	311	(30)	45	15.2	1.5	1.10	U				
	E	None	0.0014	311	90	0	18.3	0.6	2.29	U				
	E	None	0.0001	311	110	(20)	18.3	0.500	1.15	U				

TABLE B-2. EMISSIONS DATA FOR AIR MODELING: BASELINE (Continued)

Plant/ Location	Emission Type	Control Device	Benzene Rate (g/s)	Temp. (°K)	Location (m) (x)	(y)	Stack Height (m)	Stack Dia. (m)	Stack Velocity (m/s)	Emission Direction	Plant Coordinates Lat.	Long.	Temp. (°C)	Pressure (millibars)
Oxirane/TX	C	Flare	0.0380	823	0	0	33.6	0.36	0.556	U	29°49'07"	95°06'07"	21	1,016
Gulf/LA	C	Condenser	0.0003	298	(137)	164	10.52	0.05	0.1	D	30°05'44"	90°55'19"	20	1,016
	C	Condenser	0.0003	298	(82)	128	11.79	0.05	0.1	D				
	C	Condenser	0.0020	298	(68)	120	11.79	0.05	0.1	D				
	C	Condenser	0.0003	298	(53)	97	10.29	0.05	0.1	D				
	C	Flare	0.0214	993	0	0	45.72	0.41	0.17	U				
	C	Superheater	0.208	611	(119)	178	40.54	2.83	3.4	U				
	C	Reheater	0.080	566	(103)	186	46.94	1.52	4.3	U				
	E	Flare	0.0017	993	0	0	45.72	0.41	24.0	U				
Monsanto/TX	C	Scrubber	0.0047	311	(91)	(36)	4.08	0.152	0.1	H	29°22'44"	94°53'40"	21	1,017
	C	Condenser	0.0002	305	19	(58)	28.65	0.152	0.1	D				
	C	None	0.0018	324	(461)	(125)	0.76	0.102	0.1	D				
	C	None	0.0155	294	(60)	57	5.18	0.102	0.1	D				
	C	Boiler	0.0478	389	(325)	(180)	15.2	1.60	34.74	U				
	C	Superheater	0.0339	505	(108)	72	51.8	3.05	5.26	U				
	C	Superheater	0.0339	505	(108)	25	51.8	3.05	5.26	U				
	E	None	0.4899	294	42	(43)	41.1	0.050	10.76	U				
	E	Flare	0.0027	823	(25)	137	41.4	0.41	0.417	U				
Koch/TX	C	Boiler	0.006	467	0	0	30.0	1.8	12.0	U	27°49'57"	97°31'38"	22	1,014
	C	Flare	0.011	930	(49)	425	43.0	0.5	0.2	U				
	E	Flare	0.0013	930	(49)	425	43.0	0.5	25.0					
USS/TX	C	Superheater	0.0016	519	(22)	(13)	38.1	1.22	9.15	U	29°42'18"	95°15'06"	21	1,016
	C	Reboiler	0.0058	575	(5)	(1)	59.44	2.35	7.80	U				
	C	Reboiler	0.0058	575	5	1	59.44	2.35	7.80	U				
	E	None	0.0005	327	(13)	41	62.38	0.203	7.20	U				
Dow/TX A	C	Furnace	0.0228	505	43	51	39.33	2.44	3.32	U	28°57'15"	95°19'08"	21	1,016
	E	None	0.0195	294	0	0	12.2	0.076	3.65	U				

TABLE B-3. EXPOSURE AND MAXIMUM ANNUAL AVERAGE CONCENTRATIONS

Plant	Total Exposure ($\mu g/m^3$ - person)	Maximum Annual Average Concentrations ($\mu g/m^3$)
American Hoechst, LA	94	1.59×10^{-2}
American Hoechst, TX	622	1.69×10^{-2}
Amoco, TX	1,390	9.54×10^{-1}
ARCO, PA	14,700	2.09
Cos Mar, LA	449	3.96×10^{-1}
Dow, MI	24,500	1.96×10^{1}
Dow, TX (A)	188	2.1×10^{-1}
Dow, TX (B)	8,420	1.11
EL Paso Products, TX	328	7.83×10^{-2}
Gulf Oil, LA	245	3.56×10^{-2}
Monsanto, TX	6,370	1.37
Oxirane, TX	362	3.02×10^{-2}
Sun Oil, TX	30	5.07×10^{-3}
U.S. Steel, TX	190	8.21×10^{-4}

B.5.2 Example Calculations

B.5.2.1 Leukemia Incidence. As an example for calculating leukemia incidence the ARCO plant is used. Under the current level of control, the annual leukemia incidence is computed according to Equation 2 as follows:

$$\text{Annual leukemia incidence per year} = 14{,}700 \times 9.9 \times 10^{-8}$$

$$\text{Annual leukemia incidence per year} = 1.5 \times 10^{-3}$$

B.5.2.2 Maximum Lifetime Risk. Again, ARCO is used to illustrate the calculation. Under the current level of control, the maximum lifetime risk is computed according to Equation 3 as follows:

$$\text{Maximum lifetime risk} = 2.09 \times 9.9 \times 10^{-8} \times 70$$

$$\text{Maximum lifetime risk} = 1.4 \times 10^{-5}$$

B.5.3 Summary of Impacts

The methodology for calculating baseline leukemia incidence and maximum lifetime risk (described in Section B.5.1) was extended to each plant. The baseline scenario is the current level of control or the level of control to be implemented in the near future that would have occurred regardless of this standard. The estimated leukemia incidence is shown in Table B-4. The estimated nationwide leukemia cases per year under the assumed baseline level of control is about 5.7×10^{-3}. The estimated maximum lifetime risk is shown in Table B-5. The estimated maximum lifetime risk under the assumed baseline level of control is about 1.4×10^{-4}.

B.6 UNCERTAINTIES

Estimates of both leukemia incidence and maximum lifetime risk are primarily functions of estimated benzene concentrations, populations, the unit risk factor, and the exposure model. The calculations of these variables are subject to a number of uncertainties of various degrees. Some of the major uncertainties are identified below.

TABLE B-4. ESTIMATED ANNUAL LEUKEMIA INCIDENCE ($\times 10^{-4}$)

Plant	Baseline
American Hoechst, LA	0.093
American Hoechst, TX	0.62
Amoco, TX	1.4
ARCO, PA	15
Cos Mar, LA	0.44
Dow, MI	24
Dow, TX (A)	0.19
Dow, TX (B)	8.3
El Paso Products, TX	0.32
Gulf Oil, LA	0.24
Monsanto, TX	6.3
Oxirane, TX	0.36
Sun Oil, TX	0.030
U.S. Steel, TX	0.19
TOTAL	57

TABLE B-5. ESTIMATED MAXIMUM LIFETIME RISK ($X10^{-6}$)

Plant	Baseline
American Hoechst, LA	0.11
American Hoechst, TX	0.12
Amoco, TX	6.6
ARCO, PA	14
Cos Mar, LA	2.7
Dow, MI	140
Dow, TX (A)	1.5
Dow, TX (B)	7.7
El Paso Products, TX	0.54
Gulf Oil, LA	0.25
Monsanto, TX	9.5
Oxirane, TX	0.21
Sun Oil, TX	0.035
U.S. Steel, TX	0.0057

B.6.1 Benzene Concentrations

Modeled ambient benzene concentrations depend upon: (1) plant configuration; (2) emission point characteristics, which can be different from plant to plant; (3) emission rates which may vary over time, and from plant to plant; and (4) meterology, which is seldom available for a specific plant. The particular dispersion model used can also influence the numbers. Using a different dispersion model, even with the same emission data input, can produce different results. The dispersion modeling also assumes that the terrain in the vicinity of the source is flat. For sources located in complex terrain, the maximum annual concentration could be underestimated by several fold due to this assumption. Assuming the inputs to the dispersion model are accurate, the predicted benzene concentrations are considered to be accurate to within a factor of 2.

B.6.2 Exposed Populations

Several simplifying assumptions were made with respect to the assumed exposed population. The location of the exposed population depends on the accuracy of the census data in the HEM. In addition, the exposed population is assumed to be immobile, remaining at the same location 24 hours per day, 365 days per year, for a lifetime (70 years). This assumption may be counterbalanced to some extent (at least in the calculation of incidence) by the assumption that no one moves into the exposure area either permanently as a resident or temporarily as a transient. The population "at risk" was assumed to reside within 20 km of each plant, regardless of the estimated concentration at that point. The selection of 20 km is considered to be a practical modeling stop-point. The results of dispersion modeling are felt to be reasonably accurate within that distance. The dispersion coefficients used in modeling are based on empirical measurements made within 10 kilometers of sources. These coefficients become less applicable at long distances from the source, and the modeling results become more uncertain. A numerical estimate of the accuracy of these assumptions regarding the exposed population is not available.

B.6.3 Unit Risk Factor

The unit risk factor contains uncertainties associated with the occupational studies of Infante, Aksoy, and Ott, and the variations in the dose/response relationships among the studies. Other uncertainties regarding the occupational

studies and the workers exposed that may affect the unit risk factor were raised during the public comment period and focus on assumptions and inconclusive data contained in the studies. However, those uncertainties have not been quantified.

B.6.4 Other Uncertainties

There are several uncertainties associated with estimating health impacts. Maximum lifetime risk and annual incidence were calculated based on a no-threshold linear extrapolation of leukemia risk associated with a presumably healthy white male cohort of workers exposed to benzene concentrations in the parts per million range compared to the risk associated with the general population, which includes men, women, children, nonwhites, the aged, and the unhealthy, who are exposed to concentrations in the parts per billion range. It is uncertain whether these widely diverse segments of the population have susceptabilities to leukemia that differ from that of workers in the studies. Furthermore, while leukemia is the only benzene health effect considered in these calculations, it is not the only possible health effect. Other health effects, such as aplastic anemia and chromosomal aberrations, are not as easily quantifiable and are not reflected in the risk estimates. Although these other health effects have been observed at occupational levels, it is not clear if they can result from ambient benzene exposure levels. Additionally, benefits that would affect the general population as the result of indirect control of other organic emissions in the process of controlling benzene emissions from ethylbenzene/styrene plants are not quantified. Possible benzene exposures from other sources also are not included in the estimate. For example, an individual living near an ethylbenzene/ styrene plant is also exposed to benzene emissions from automobiles. Finally, these estimates do not include possible cumulative or synergistic effects of concurrent exposure to benzene and other substances.

B.7 REFERENCES

1. U.S. Environmental Protection Agency. Industrial Source Complex (ISC) Dispersion Model User's Guide, Volume I. Research Triangle Park, North Carolina. EPA-450/4-79-031. 1979

2. U.S. Environmental Protection Agency. An Evaluation Study for the Industrial Source Complex (ISC) Dispersion Model. Research Triangle Park, North Carolina. EPA-450/4-81-002. 1981.

3. Systems Applications, Inc. Human Exposure to Atmospheric Concentrations of Selected Chemicals. (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina). Volume I (NTIS No. PB 81 193252) and Volume II (NTIS No. PB 81 193260). May 1980.

4. Albert , R. E. Carcinogen Assessment Group's Final Report on Population Risk to Ambient Benzene Exposures. U.S. Environmental Protection Agency. Publication No. EPA-450/5-80-004. January 1979.